

Chapter VI: Cost-Effectiveness

This Section will present the cost-effectiveness analysis we completed for the combined Tier 2 exhaust, Tier 2 evaporative, and gasoline sulfur standards. This analysis relies in part on cost information from Section V and emissions information from Section III to estimate the dollars per ton of total NO_x + NMHC emission reductions after the Tier 2 standards have been fully implemented. The tons reduced used in this analysis are the same as those used in our air quality modeling analysis. We have also expanded our cost-effectiveness analysis from that presented in the NPRM to include another approach, aggregate cost-effectiveness, which accounts for all costs and emission reductions over a 30 year period beginning in 2004. Finally, this Section compares the cost-effectiveness of the new provisions with the cost-effectiveness of other NO_x and NMHC control strategies from previous and potential future EPA emission control programs. Our responses to comments submitted to us on the subject of cost-effectiveness can be found in the Response To Comments document, Issue Number 24.

The emission reductions used to calculate the cost-effectiveness levels reported here are based on those reductions used for our air quality analysis modeling and benefits analysis. This was done to maintain consistency in the analyses. As noted in section III.A, we have updated our inventory model since the air quality modeling inventories were calculated. Table III.A.-3 compares the updated Tier 2 model with the air quality analysis modeling and shows that the emission reductions expected from Tier 2/gasoline sulfur will be substantially greater than the amounts originally calculated. If the updated numbers were incorporated into our cost-effectiveness we would expect the results to be improved over those shown in this section.

A. Overview of the Analysis

We have calculated the cost-effectiveness of the exhaust emission/gasoline sulfur standards and the evaporative emission standards, based on two different approaches. The first considers the net present value of all costs incurred and emission reductions generated over the life of an average Tier 2 vehicle. This per-vehicle approach focuses on the cost-effectiveness of the program from the point of view of the Tier 2 vehicles which will be used to meet the new requirements, and is the method used in our proposal. However, the per-vehicle approach does not capture all of the costs or emission reductions from the Tier 2/gasoline sulfur program since it does not account for the use of low sulfur gasoline in pre-Tier 2 vehicles. Therefore, we have also calculated an aggregate cost-effectiveness using the net present value of costs and emission reductions for all in-use vehicles over a 30-year time frame. Both approaches have been used in previous mobile-source programs, though the per-vehicle approach is more common.

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Sections A through C describe how we developed our per-vehicle cost-effectiveness results. This is followed, in Section D, with the extension of these techniques to the aggregate cost-effectiveness. All of our results are then presented and discussed in Section E.

The per-vehicle cost-effectiveness analysis conducted for our standards focused on the costs and emission reductions associated with a single vehicle meeting the Tier 2 emission standards, and operating on low sulfur fuel. Both costs and emission reductions were calculated over the life of the vehicle and then discounted at a rate of seven percent. Costs and emission reductions were measured relative to an NLEV baseline and average sulfur levels in the absence of sulfur controls. The calculations were performed separately for each vehicle class and the results weighted according to the expected fleet mix. Details on this approach to cost-effectiveness follow.

1. Temporal and Geographic Applicability

The per-vehicle approach to our cost-effectiveness calculations produces \$/ton values representing any controlled vehicle, no matter where that vehicle operates. In effect, this means that emission reductions in both attainment and nonattainment areas are included in our cost-effectiveness analysis. We believe that this is appropriate. Both the Tier 2 vehicle and gasoline sulfur programs are to apply nationwide, so that the same emission reductions will occur regardless of where the vehicle operates. Attainment area emission reductions also produce health benefits. In general, the benefits of NMHC reductions in ozone attainment areas include reductions in emissions of air toxics, reductions in the contribution from NMHC emissions to the formation of fine particulate matter, and reductions in damage to agricultural crops, forests, and ecosystems from ozone exposure. Emission reductions in attainment areas help to maintain clean air as the economy grows and new pollution sources come into existence. Also, ozone health benefits can result from reductions in attainment areas, although the most certain health effects from ozone exposure below the NAAQS appear to be both transient and reversible. The closure letter from the Clean Air Science Advisory Committee (CASAC) for the recent review of the ozone NAAQS states that there is no apparent threshold for biological responses to ozone exposure¹.

In the Regulatory Impact Analysis for a recent rulemaking for highway heavy-duty diesel engine standards², EPA also presented a regional ozone control cost-effectiveness analysis in which the total life-cycle cost was divided by the discounted lifetime NO_x + NMHC emission reductions adjusted for the fraction of emissions that occur in the regions expected to impact ozone levels in ozone nonattainment areas. (Air quality modeling indicates that these regions include all of the states that border on the Mississippi River, all of the states east of the Mississippi River, Texas, California, and any remaining ozone nonattainment areas west of the Mississippi River not already included.). The results of that analysis show that the regional cost-effectiveness values were 13 percent higher than the nationwide cost-effectiveness values.

Because of the small difference between the two results, EPA is presenting only nationwide cost-effectiveness results for this analysis.

Despite the fact that a per-vehicle approach to cost-effectiveness allows us to avoid the arbitrary choice of a specific year in which to conduct the analysis, there is some value in examining different points in time after the program is first implemented. The costs of the program will be higher immediately after it is implemented than they will be after several years, since both vehicle manufacturers and refiners can take advantage of decreasing capital and operating costs over time. For the purposes of this rulemaking, therefore, we will present cost-effectiveness of our program on both a near-term and long-term basis. More details concerning per-vehicle costs are given in Section VI.B.1.

2. Baselines

There are two broad approaches to cost-effectiveness that can be taken, each of which requires a different baseline. These two approaches can be termed "incremental" and "average." Both incremental and average approaches to cost-effectiveness provide a measure of how much more stringent than the existing standards our standards can be before they cease to be cost-effective.

An incremental approach to cost-effectiveness requires that we evaluate a number of different potential standards, each of which is compared to the potential standards closest to it. Using this approach, the cost-effectiveness of our standards would be calculated with respect to another set of potential standards which is less stringent than our standards. In this way, the \$/ton values represent the last increment of control, highlighting any nonlinearities that exist in either the costs or emission reductions.

An average approach to cost-effectiveness, on the other hand, requires that we compare the costs and emission reductions associated with our standards to those for the previous set of standards that are being met by manufacturers. In this case, the \$/ton values represent the full range of control from the last applicable standard to our standards.

Incremental cost-effectiveness will produce different \$/ton values than an average approach to cost-effectiveness only if the costs or emission reductions are nonlinear. In the case of our standards, both the emission reductions and the fuel cost as a function of sulfur content are nearly linear, though the vehicle costs do contain some nonlinearity. In addition, nearly all past mobile source programs have calculated cost-effectiveness with respect to the previous set of standards. Therefore, we have chosen to calculate cost-effectiveness on an average rather than an incremental basis.

Since today's program includes both fuel standards and vehicle standards, it was

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necessary for us to define a baseline for both fuels and vehicles. For fuels, there are no previous controls applicable to sulfur (apart from an ASTM limit of 1000 ppm). As a result, we have determined that the sulfur baseline should represent the national average sulfur level that would exist at the time our sulfur standard would go into effect. The national average sulfur content of current conventional gasoline is approximately 300 ppm.. This is a change from the NPRM value of 330 ppm based on more recent survey data. We are not projecting the sulfur level of conventional gasoline to change over the next ten years in the absence of specific sulfur controls. For Phase II reformulated gasoline (RFG), the average sulfur content is projected to be 150 ppm in the summer and 300 ppm in the winter¹. Based on the fact that the high ozone season covers approximately 4.5 months, we estimate that 38 vol% of the annual pool is summer gasoline, with the remainder being winter gasoline. Applying these fractions to the Phase II RFG sulfur levels produces an annual sulfur level of 240 ppm. Because estimating the number of areas that will continue to be in the RFG program by the middle of the next decade is highly speculative, we have assumed that the current volume split between RFG and conventional gasoline will continue indefinitely. Thus we estimated that Phase II RFG will account for 26.7 percent of the total gasoline pool. As a result, we calculated the national average sulfur level for the next decade to be 285 ppm. This is the baseline sulfur level used in our calculations.

For the exhaust emission standards applicable to light-duty vehicles and trucks, there are two potentially valid baselines that could be used. The Clean Air Act (CAA) suggests that Tier 2 vehicle standards should be compared to the previous set of federal light-duty standards, termed Tier 1 standards. However, the language does not explicitly require that the cost-effectiveness determination use Tier 1 standards as the baseline. Since the passage of the CAA Amendments of 1990, the National Low Emission Vehicle (NLEV) program has gone into effect. NLEV includes light-duty standards that are more stringent than Tier 1 for LDV, LDT1, and LDT2. NLEV did not exist in 1990 and was not envisioned by the authors of the CAA Amendments of 1990. Had NLEV existed, either in concept or as a formal program, we believe that it could have been identified in the CAA as the point of comparison for evaluating Tier 2 standards. In addition, NLEV standards represent the most recent set of standards with which manufacturers must comply. For our proposal, therefore, we have decided to make NLEV the baseline on which the vehicle side of our cost-effectiveness calculations are based. Further, these NLEV vehicles would be SFTP compliant since they would be sold in 2004 (the first year of our Tier 2 program).

The NLEV program did not include new standards for evaporative emissions, and so cannot be used as the baseline for evaluating the cost-effectiveness of our Tier 2 evaporative emission standards. Instead, the 2.0 gram/test standards under the enhanced evaporative

¹ Based on a consensus opinion of the multi-party Phase II RFG Implementation Team, and summarized in a report entitled, "Phase II RFG Report on Performance Testing." Contact: Deborah Wood, Office of Mobile Sources.

procedure, initially implemented in 1996, have been used as the baseline.

B. Costs

The costs used in our per-vehicle cost-effectiveness calculations are the sum of the costs of compliance with the Tier 2 exhaust, Tier 2 evaporative, and gasoline sulfur standards on a per-vehicle basis. Costs result from discounting over the lifetime of a vehicle at a seven percent discount rate. In addition, all costs represent the fleet-weighted average of light-duty vehicles and trucks.

1. Near and Long-Term Cost Accounting

Since the costs of complying with both the Tier 2 exhaust and gasoline sulfur standards will vary over time, we determined that it is appropriate to consider both near-term and long-term costs in our cost-effectiveness analysis. First, the capital costs associated with the manufacture of vehicles that meet the Tier 2 standards are generally amortized over five years. Thus in the sixth year of production, a portion of the capital costs become zero and the total costs of production drop. Manufacturers also gain knowledge about the best way to meet new standards as time goes on, and as a result their operating costs decrease over time. As described in a recent rulemaking setting standards for non-road compression ignition engines, we have determined that the cost-implications of this "learning curve" can be estimated as a 20 percent drop in operating costs in the third year of production.

Thus near-term costs represent the highest costs of the program, as they include all capital costs and no cost savings due to the manufacturer's learning curve. Long-term costs, on the other hand, represent the lowest costs of the program which occur after a portion of capital cost amortization has ended and all learning curve cost savings have been accounted for. For the purposes of this rulemaking, therefore, we will present cost-effectiveness of our program on both a near-term and long-term basis.

Because of our per-vehicle approach to cost-effectiveness, near-term and long-term costs are not associated with any specific year of our Tier 2 program. For instance, the costs associated with our gasoline sulfur control program will decline in steps due to rotating capital expenditures. Vehicle costs, however, decline over a different schedule. Not only are the vehicle-related capital costs amortized over five years instead of the longer, rotating schedule for gasoline sulfur, but the phase-in schedule for the Tier 2 exhaust standards varies depending on vehicle class. Therefore, the near-term costs actually represent a conservative view of the costs of our program, since they consider the highest vehicle and fuel costs as if they occurred at the same time for all vehicle classes. The long-term costs, on the other hand, represent the case for some later year of the Tier 2/gasoline sulfur program in which a majority of the fleet is meeting

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our standards. In this case, the phase-in schedule for light-duty vehicles and trucks is no longer evident in the fleet mix, a portion of capital cost amortization has ended, and most learning curve cost savings will have been taken into account. Details about the calculation of near and long-term vehicle and fuel costs can be found in Sections V.A.1 and V.B.2.

2. Vehicle and Fuel Costs

The per-vehicle costs used in our cost-effectiveness calculations were derived and presented in the preceding sections. Vehicle costs were presented in Table V-12 for the five vehicle categories affected by our standards. For the purposes of calculating cost-effectiveness, we first subtracted out the costs attributable to compliance with our evaporative emission standards, then weighted the remaining costs for those five individual vehicle categories by the expected fleet fractions to obtain fleet-average costs for our exhaust emissions standards. Also, we treated first-year production costs as the "near-term" costs, and sixth-year production costs as the "long-term" costs. Costs associated with compliance with our evaporative emission standards were constant across all vehicle classes at \$4.10 per vehicle. For low sulfur gasoline, we used the discounted lifetime costs presented in Table V-46. The costs used in our cost-effectiveness calculations are repeated in Table VI-1.

Table VI-1. Fleet-average, Per-vehicle Costs Used in Cost-effectiveness

	<i>Vehicle-exhaust (\$)</i>	<i>Vehicle-evap (\$)</i>	<i>Fuel (\$)</i>	<i>Total costs (\$)</i>
Near-term	121.04	4.10	117.82	242.96
Long-term	89.56	4.10	111.01	204.67

Note that the total costs in Table VI-1 were used for establishing "uncredited" cost-effectiveness values. As described in the next section, the costs from Table VI-1 were also adjusted to produce "credited" cost-effectiveness values.

3. Cost Crediting for PM and SO₂

The object of our cost-effectiveness analysis is to compare the costs to the emission reductions in an effort to assess the program's efficiency in helping to attain and maintain the NAAQS. Thus we recognize that the primary purpose of our standards is to reduce emissions of hydrocarbon and oxides of nitrogen emissions from the affected vehicles. That is why we determined that cost-effectiveness should be calculated on the basis of total NO_x + NMHC

emissions. However, we also believe that reductions in other pollutants which produce health or welfare benefits should be included in the cost-effectiveness assessment, since they also represent a value of our program.

The reduction in gasoline sulfur levels that would result from our standards will necessarily result in reductions in sulfur-containing compounds that exit the tailpipe. These compounds are limited to sulfur dioxide (SO₂) and sulfate particulate matter. We are not setting Tier 2 standards in order to control emissions of SO₂, so we have not calculated the cost-effectiveness of SO₂ control. Likewise for sulfate PM, manufacturers are already meeting the Tier 2 PM standard, so that there are no additional costs for compliance and PM cost-effectiveness is not relevant. However, reductions in emissions of SO₂ and sulfate PM represent real benefits of our program, and it is appropriate to account for them in some way in our cost-effectiveness calculations. To do this, we have calculated a second set of \$/ton values in which we credit some of the costs to SO₂ and direct sulfate PM, with the remaining costs being used to calculate \$/ton NO_x+NMHC. As a result, we have produced both "credited" and "uncredited" \$/ton NO_x+NMHC values; the former takes into account the SO₂ and direct PM emission reductions associated with our standards, while the latter does not.

Cost-effectiveness values for the control of SO₂ and direct PM represent conservative estimates of the cost of measures that will need to be implemented in the future in order for all areas to reach attainment. Such cost-effectiveness values are therefore an appropriate source for estimating the amount of the costs to credit to these pollutants. As a result, we credited some costs to SO₂ and direct PM through the application of cost-effectiveness (\$/ton) values for these two pollutants drawn from other sources.

In concept, we would consider the most expensive program needed to reach attainment to be a good representation of the ultimate value of PM or SO₂. However, in this rulemaking, we chose to simplify by using more conservative approaches to establish crediting values for PM and SO₂. The potential future programs evaluated as part of the NAAQS revisions rulemaking (discussed in more detail in Section VI.E below) provided a reasonable source for identifying the value of SO₂ and direct PM in terms of their cost-effectiveness.

Out of the nine SO₂ control programs evaluated in the NAAQS revisions rule, eight were actually used in the modeling of ambient concentrations of PM based on their contribution to secondary PM (sulfate) levels in PM nonattainment areas. The cost-effectiveness of the eight SO₂ control programs ranged from \$1600/ton to \$111,500/ton. In this particular rulemaking, we have for simplicity's sake used the average cost effectiveness of the eight SO₂ control programs, calculated to be \$4800 a ton. This average value of \$4800/ton was used in the crediting of some costs to SO₂, and represents a conservative valuation of SO₂.

The NAAQS revisions rule also evaluated PM control strategies, accounting for both PM₁₀ and PM_{2.5}. The average cost-effectiveness for the PM control strategies considered in the

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NAAQS revisions rule ranged from \$2,400/ton (for PM₁₀) to \$12,900/ton (for PM_{2.5}). The particulate matter that would be reduced as a result of our Tier 2/gasoline sulfur program could be categorized as fine PM having mean particle diameters of less than 2.5 microns. Despite the fact that the revised NAAQS for PM was remanded, PM_{2.5} remains a bigger health hazard than PM₁₀, and it is therefore still valid to examine cost-effectiveness values for both PM₁₀ and PM_{2.5}. Furthermore, a recent rulemaking setting standards for urban busses³ determined that the cost-effectiveness of PM control for these heavy-duty diesel engines was \$10,000 - \$16,000/ton. In this particular rulemaking, rather than attempt to identify an more precise credit value for PM based on the last measures needed for attainment, we have for simplicity's sake used \$10,000/ton as a conservative but reasonable crediting value for PM for our standards.

The cost crediting was applied after all costs associated with compliance with our standards were calculated and summed. The per-vehicle tons reduced of both direct PM and SO₂ were multiplied by the respective cost-effectiveness values of \$10,000/ton and \$4800/ton (see Sections VI.C.3 and VI.C.4 below for tons calculations). As a result, \$50.61 of the total costs were apportioned to SO₂, while \$3.72 was apportioned to direct PM. These amounts are independent of whether we are considering a near-term or long-term cost-effectiveness calculation, since the lifetime tons reduced for these two compounds is the same, on a per-vehicle basis, in any year of the program. A summary of the costs used in our cost-effectiveness calculations is given below in Table VI-2.

Table VI-2. Fleet Average Per-vehicle Costs Used in Cost-effectiveness

	<i>Near-term costs (\$)</i>	<i>Long-term costs (\$)</i>
Total uncredited costs	242.96	204.67
SO ₂ credit allocation	-50.61	-50.61
Direct PM credit allocation	-3.72	-3.72
Total credited costs	188.63	150.34

C. Emission Reductions

In order to determine the overall per-vehicle cost-effectiveness of the standards we are proposing, it was necessary to calculate the lifetime tons of each pollutant reduced on a per vehicle basis. This section will describe the steps involved in these calculations. In general, emission reductions were calculated for NO_x, NMHC, sulfate PM, and SO₂ in a manner

analogous to the discounted lifetime fuel costs described in Section V.B.4.

1. NO_x and NMHC

Our standards are intended primarily to reduce emissions of NO_x and NMHC. As a result, we have determined that the cost-effectiveness of our standards should be determined for both NO_x and NMHC. It is true the our program does include new standards for PM. However, these standards are already being met by manufacturers. Thus manufacturers will incur no new costs to comply with the Tier 2 PM standard and a cost-effectiveness analysis of the PM standards is therefore unnecessary.

Several past rulemakings which produced reductions in both NO_x and NMHC have taken an approach to cost-effectiveness that sums the NO_x and NMHC emission reductions. This approach leads to \$/ton NO_x+NMHC. In addition, many standards for mobile sources have been established in terms of NO_x+NMHC caps. Thus we believe that this approach to cost-effectiveness is appropriate for our Tier 2 standards as well, because we are proposing more stringent exhaust standards for both NO_x and NMHC (separately). This approach also allows for a direct comparison to previous programs for which NO_x and NMHC were summed in the cost-effectiveness analyses.

The discounted lifetime tonnage numbers for NO_x, exhaust NMHC, and evaporative NMHC were based on average in-use emission levels developed for EPA's MOBILE6 on-highway inventory model. These in-use emission levels were expressed in terms of average gram/mile emissions for each year in a vehicle's life, up to 25 years. From this basis, lifetime tonnage estimates were developed using the following procedure:

- 1) Annual mileage accumulation levels for MOBILE6 were applied to the in-use emission rates for each year in a vehicle's life to generate total mass emissions produced in each year by that vehicle.
- 2) The resultant mass emissions were multiplied by the probability of survival in the appropriate year, known as the "survival" rate, from estimates for cars and trucks published by NHTSA⁴.
- 3) A seven percent annual discount factor, compounded from the first year of the vehicle's life, was then applied for each year to allow calculation of net present value lifetime emissions.

Converting to tons and summing across each year results in the total discounted lifetime per-vehicle tons. This calculation can be described mathematically as follows:

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$$LE = \sum [(AVMT)_i \cdot (SURVIVE)_i \cdot (ER)_i \cdot (K)] / (1.07)^{i-1}]$$

Where:

LE	= Discounted lifetime emissions in tons/vehicle
(AVMT) _i	= Annual vehicle miles traveled in year i of a vehicle's operational life
(SURVIVE) _i	= Probability of vehicle survival after i years of service
(ER) _i	= Emission rate, g/mi in year i of a vehicle's operational life
K	= Conversion factor, 1.102 x 10 ⁻⁶ tons/gram
i	= Vehicle years of operation, counting from 1 to 25

For NO_x and exhaust NMHC, we generated discounted lifetime tonnage values for each vehicle class (LDV, LDT1, LDT2, LDT3, LDT4, where LDT4 includes MDPV) using the above equation. This was done separately for the baseline and control cases. The baseline case included the NLEV vehicle program (LEV for LDV, LDT1 and LDT2; Tier 1 for LDT3 and LDT4) and the in-use fuel program (RFG in the appropriate areas, modeled at 150 ppm sulfur for the summer and 300 ppm for the winter; conventional gasoline in the remaining areas, modeled at 300 ppm sulfur year-round). The control case entailed the Tier 2 vehicle program (0.07 g NO_x/mi and 0.09 g NMHC/mi for all vehicle classes) and fuel program (30 ppm nationwide). Baseline and controlled sulfur levels also included the maximum sulfur levels that would be seen by a vehicle over its lifetime in order to estimate the impacts of catalyst irreversibility as described in Section VI.C.2 below. Thus the actual number of sulfur cases was four: two for the average baseline and control sulfur levels, and two more for the maximum baseline and control sulfur levels. For each permutation of vehicle and fuel program, tonnage estimates were also developed for IM and non-IM areas to allow generation of a nationwide composite tonnage estimate. The tonnage values that we calculated according to this procedure are presented in Appendix VI-A.

Before using the tonnage values to calculate the cost-effectiveness of our program, it was necessary for us to combine the values for IM vs. no-IM areas and RFG vs. conventional gasoline areas in an effort to represent the national scope of our program. The weighting factors were based on an analysis of the fraction of the population in the 47 state area (U.S. excluding California, Alaska, and Hawaii) which was located within or outside of IM and RFG areas⁵. We also made a distinction between summer and winter RFG, since summer-grade Phase II RFG having approximately 150 ppm sulfur will be used for only 38 percent of the year, while winter-grade Phase II RFG having approximately 300 ppm sulfur will be used for the remaining 62 percent of the year. 1998 population data was used to determine these population fractions by state, and then nationwide weighting factors were produced from the sum of these fractional by-state populations. The geographical results are shown in Table VI-3.

Table VI-3. Weighting Factors for NOx and NMHC Lifetime Tonnage Values

<i>RFG program area?</i>	<i>IM program area?</i>	<i>Fraction of population</i>
Yes	Yes	0.248
Yes	No	0.019
No	Yes	0.228
No	No	0.505

For evaporative NMHC, we based the baseline tonnage values on gram/mile emissions projected by MOBILE5b. To model our control case, we projected the gram/mile emissions using the version of MOBILE5b which was modified to reflect the benefits of our Tier 2 controls. We used gram/mile emission factors from 2030 to reflect a baseline fleet consisting entirely of Enhanced Evaporative vehicles, and a control fleet consisting of essentially all Tier 2 vehicles⁶. The evaporative tonnage values are presented in Appendix VI-B.

The final step before calculating the cost-effectiveness of our program was to weight the discounted lifetime tonnage values for each vehicle class by their respective fraction of the fleet. These fractions were developed based on our projection that LDT sales will stabilize at 60 percent of the light-duty market by 2008. This value is based on sales data projected by auto manufacturers for 1998 model year certification. Table VI-4 presents the final weighting factors we used to develop fleet-average tonnage values.

Table VI-4. Vehicle Class Sales Weighting Factors

LDV	0.400
LDT1	0.102
LDT2	0.340
LDT3	0.103
LDT4	0.055

The values in Table VI-4 differ slightly from those in the draft RIA due to the inclusion of larger trucks above 8500 lb GVWR (a class now called medium duty passenger vehicles, or MDPV) into the LDT4 category. The final discounted lifetime tonnage values in the absence of sulfur irreversibility effects for an average fleet vehicle meeting either the standards for NLEV or our

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Tier 2 standards are shown in Tables VI-5 and VI-6, respectively.

Table VI-5. Fleet-average, Per-vehicle Discounted Lifetime Tons for the NLEV Baseline

<i>Sulfur (ppm)</i>	<i>NOx (tons)</i>	<i>Exhaust NMHC (tons)</i>	<i>Evap NMHC (tons)</i>
800 ²	0.14331	0.03686	0.04192
285	0.11556	0.03319	0.04192

Table VI-6. Fleet-average, Per-vehicle Discounted Lifetime Tons for Tier 2 Standards

<i>Sulfur (ppm)</i>	<i>NOx (tons)</i>	<i>Exhaust NMHC (tons)</i>	<i>Evap NMHC (tons)</i>
80	0.03565	0.02369	0.03887
30	0.02744	0.02250	0.03887

The values in Tables VI-5 and VI-6 were not used in the cost-effectiveness calculations directly. Instead, the effects of irreversibility were first calculated according to the methodology described in Section VI.C.2 below using the tonnage values from the tables above.

2. Irreversibility

As described in Appendix B, we believe that Tier 1, LEV, and Tier 2 vehicles meeting the SFTP standards will exhibit an increased tendency towards sulfur poisoning of their catalysts. As a result of sulfur poisoning, catalyst efficiency is reduced and emissions increase. Since all vehicles are currently certified on low sulfur fuel, current in-use emissions can be expected to be higher than certification levels.

² Tonnage values at 800 ppm and 80 ppm sulfur were used for estimating the impacts of irreversibility. See Section VI.C.2 for details.

The increased emissions that result when an SFTP-compliant vehicle is run on high sulfur fuel is a function of the "sulfur sensitivity" of the catalyst. This aspect of sulfur poisoning has been taken into account in our cost-effectiveness analysis by virtue of the fact that the change in lifetime tons reduced is a function of our gasoline sulfur standard. The impacts of the sulfur sensitivities on emissions for pre-SFTP and post-SFTP compliant vehicles are described in an EPA Technical Report⁷.

However, one aspect of sulfur poisoning requires special treatment in our cost-effectiveness analysis. In SFTP-compliant vehicles, some sulfur poisoning due to the use of high sulfur fuel often extends well beyond the time that high sulfur fuel is actually used. When an SFTP-compliant vehicle returns to using low sulfur gasoline after having been operated on high sulfur fuel, a degree of poisoning remains. This effect is termed "irreversibility," and is described in detail in Appendix B. We have estimated that the irreversibility effect for SFTP-compliant vehicles will be in the range of 20 to 65 percent, meaning that 20 to 65 percent of the emission reductions that would otherwise occur when changing from high to low sulfur fuel are lost due to permanent sulfur poisoning of the catalyst. That is to say, 20 to 65 percent of the sensitivity effect is permanent or "irreversible" regardless of the fuel sulfur level.

While it is possible that the irreversibility effect can be reduced or eliminated under certain driving conditions, such as high temperature/high load driving, we believe that this is unlikely for SFTP-compliant vehicles. The data regarding catalyst cleanup conditions for future vehicles is quite limited. Lacking data to support the recovery of full catalyst functionality, our analysis treats irreversibility as a permanent effect.

Since our cost-effectiveness analysis makes use of emissions summed over the life of a vehicle, we must account for the fact that there may have been hundreds of refuelings in that time frame with repeated switches between low and high sulfur fuel. Since the higher sulfur fuels will be widely available, we expect vehicles to be exposed to such fuels early in their lives. As a result, the irreversibility effect will be present for most of these vehicles' lifetimes. Irreversibility effects on lifetime emissions can then be calculated as the difference between lifetime emissions at high sulfur fuel and lifetime emissions at the average fuel sulfur level.

Under our gasoline sulfur program, the average sulfur level will be 30 ppm and the maximum allowable level will be 80 ppm after full implementation. Per-vehicle lifetime emissions at these two sulfur levels from Table VI-6 were used to determine the effect of irreversibility on Tier 2 vehicles. For simplicity, we have used the midpoint of our estimated range of irreversibility effects, 42.5 percent. The Tier 2 lifetime tonnage values for NO_x and exhaust NMHC at 30 ppm, which included the effects of irreversibility and which was actually used in our cost-effectiveness analysis, was calculated from the following equation:

$$ILE_{30} = (IE) \cdot (LE_{80} - LE_{30}) + LE_{30}$$

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Where:

- ILE_{30} = Irreversibility-impacted, discounted lifetime emissions of Tier 2 vehicles at 30 ppm sulfur in tons/vehicle, for each vehicle class
- IE = Irreversibility impact, 0.425
- LE_{80} = Discounted lifetime emissions of Tier 2 vehicles at 80 ppm sulfur in tons/vehicle, for each vehicle class
- LE_{30} = Discounted lifetime emissions of Tier 2 vehicles at 30 ppm sulfur in tons/vehicle, for each vehicle class

For the NLEV vehicles forming our baseline, the average sulfur level was established as 285 ppm as described in Section VI.A.3 above. Apart from an ASTM maximum allowable value of 1000 ppm, there is no regulated in-use maximum value for gasoline sulfur. However, after the year 2000, we project that more than 95 percent of gasoline will contain sulfur levels below 800 ppm. We have therefore chosen 800 as the maximum sulfur level on which NLEV vehicles will be operated. It could be argued that 1000 ppm is a more appropriate value to represent the maximum (or even higher, as a few in-use batches of gasoline exceed the ASTM limit). We believe that a maximum of 800 ppm is more representative of the maximum sulfur level that the average NLEV vehicle will be operated on, since very few vehicles will ever see sulfur levels as high as 1000 ppm.

Per-vehicle lifetime emissions at 285 ppm and 800 ppm from Table VI-5 were used to determine the effect of irreversibility on vehicles meeting NLEV standards. As discussed in Appendix B, we believe that irreversibility applies to any SFTP-compliant vehicle, including LDT3 and LDT4 meeting Tier 1 standards under the NLEV program. Thus the calculations followed the same procedure as that used for Tier 2 vehicles:

$$ILE_{285} = (IE) \cdot (LE_{800} - LE_{285}) + LE_{285}$$

Where:

- ILE_{285} = Irreversibility-impacted, discounted lifetime emissions of SFTP-complaint NLEV vehicles at 285 ppm sulfur in tons/vehicle, for each vehicle class
- IE = Irreversibility impact, 0.425
- LE_{800} = Discounted lifetime emissions of NLEV vehicles at 800 ppm sulfur in tons/vehicle, for each vehicle class
- LE_{305} = Discounted lifetime emissions of NLEV vehicles at 285 ppm sulfur in tons/vehicle, for each vehicle class

After assessing the impact of irreversibility on both Tier 2 and NLEV vehicles, we were able to develop a final set of discounted lifetime tonnage values that were actually used in our cost-effectiveness analysis. These values are given in Table VI-7.

Table VI-7. Fleet-average, Per-vehicle Discounted Lifetime Tons Used in Cost-effectiveness Analysis

	<i>NOx (tons)</i>	<i>Exhaust NMHC (tons)</i>	<i>Evap NMHC (tons)</i>	<i>Total NOx + NMHC (tons)</i>
Baseline: NLEV at 285 ppm	0.12735	0.03475	0.04192	0.20402
Target: Tier 2 at 30 ppm	0.03093	0.02300	0.04020	0.09413

3. Primary Particulate Matter

Vehicles meeting our standards will produce reductions in both primary and secondary particulate matter. As described in Section VI.B.3 above, we are accounting for reductions in primary (sulfate) PM in our cost-effectiveness analysis. Although secondary PM reductions are not being accounted for in our cost-effectiveness analysis, they have been included in our analysis of the health and welfare benefits of our program, as described in Section VII.

Primary PM emission reductions result from the removal of sulfur in gasoline, which produces a commensurate reduction in the amount of sulfate PM emitted from the tailpipe. To calculate the reduction, we have assumed that sulfate PM accounts for 1 percent of all sulfur exiting the tailpipe on a molar basis. Primary sulfate PM exists almost entirely as sulfuric acid, and is generally hydrated. We have assumed seven hydrations, consistent with the approach taken in the development of EPA's NON-ROAD emissions model.

Discounted lifetime tons of primary PM reduced as a result of our gasoline sulfur standard are calculated according to the following equation:

$$LE = \sum [\{ (AVMT)_i \cdot (SURVIVE)_i \div (FE) \cdot (D) \cdot (SUL) \cdot (F) \cdot (MC) \cdot (K) \} / (1.07)^{i-1}]$$

Where:

LE = Discounted lifetime emissions of primary PM in tons/vehicle
 (AVMT)_i = Annual vehicle miles traveled in year i of a vehicle's operational life
 (SURVIVE)_i = Fraction of vehicles still operating after i years of service
 FE = Fuel economy by vehicle class (see Section VI.B.4)
 D = Density of gasoline, 6.17 lb/gal

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SUL	= Change in gasoline sulfur concentration, 2.55×10^{-4} lb sulfur/lb fuel (255 ppm)
F	= Fraction of total sulfur which exits the tailpipe as primary PM, 0.01
MC	= Molar conversion factor, 7 lb sulfuric acid per lb sulfur
K	= Conversion factor, 5.0×10^{-4} tons/lb
i	= Vehicle years of operation, counting from 1 to 25

After applying the above equation separately for each vehicle class and weighting the resulting tonnage values according to the factors presented in Table VI-4, we determined that the fleet-average, per-vehicle discounted lifetime tons of primary PM reduced is 0.00037. This is the value that was used to determine the PM-based credit that was applied to the total costs as described in Section VI.B.3 and summarized in Table VI-2.

4. Sulfur Dioxide

The sulfur contained in gasoline exists the tailpipe as either sulfuric acid, a component of primary particulate matter, or as sulfur dioxide (SO_2). As described in Section VI.C.2 above, we have assumed that sulfate PM, as hydrated sulfuric acid, accounts for 1 percent of all sulfur exiting the tailpipe on a molar basis. Thus the remaining 99 percent of sulfur exiting the tailpipe is in the form of SO_2 .

Discounted lifetime tons of SO_2 reduced as a result of our gasoline sulfur standard are calculated according to the following equation:

$$\text{LE} = \sum [\{(\text{AVMT})_i \cdot (\text{SURVIVE})_i \div (\text{FE}) \cdot (\text{D}) \cdot (\text{SUL}) \cdot (\text{F}) \cdot (\text{MC}) \cdot (\text{K})\} / (1.07)^{i-1}]$$

Where:

LE	= Discounted lifetime emissions of SO_2 in tons/vehicle
$(\text{AVMT})_i$	= Annual vehicle miles traveled in year i of a vehicle's operational life
$(\text{SURVIVE})_i$	= Fraction of vehicles still operating after i years of service
FE	= Fuel economy by vehicle class (see Section VI.B.4)
D	= Density of gasoline, 6.17 lb/gal
SUL	= Change in gasoline sulfur concentration, 2.55×10^{-4} lb sulfur/lb fuel (255 ppm)
F	= Fraction of total sulfur which exits the tailpipe as SO_2 , 0.99
MC	= Molar conversion factor, 2 lb SO_2 per lb sulfur
K	= Conversion factor, 5.0×10^{-4} tons/lb
i	= Vehicle years of operation, counting from 1 to 25

After applying the above equation separately for each vehicle class and weighting the resulting tonnage values according to the factors presented in Table VI-4, we determined that the

fleet-average, per-vehicle discounted lifetime tons of SO₂ reduced is 0.01054. This is the value that was used to determine the SO₂-based credit that was applied to the total costs as described in Section VI.B.3 and summarized in Table VI-2.

D. Aggregate Cost-Effectiveness

Since the per-vehicle approach to cost-effectiveness considers only Tier 2 vehicles, it does not reflect the costs and emission reductions from pre-Tier 2 vehicles operating on low sulfur gasoline. An alternative approach for evaluating the cost-effectiveness of our program involves calculating the net present value of all nationwide emission reductions and costs for a 30 year period. This timeframe captures both the early period of the program when very few Tier 2 vehicles will be in the fleet, and the later period when essentially all vehicles in the fleet will meet Tier 2 standards. We have calculated this "aggregate" cost-effectiveness using the net present value of the annual emission reductions and costs. The calculation of aggregate cost-effectiveness follows the pattern described above for the per-vehicle analysis:

$$DNAE = \sum (NE)_i / (1.07)^{i-2004}$$

Where:

DNAE = Reduction in discounted, nationwide aggregate emissions in tons
(NE)_i = Reduction in nationwide emissions in tons for year i of the program
i = Year of the program, counting from 2004 to 2034

and

$$DNAC = \sum (NC)_i / (1.07)^{i-2004}$$

Where:

DNAC = Discounted, nationwide aggregate costs in dollars
(NC)_i = Nationwide costs in dollars for year i of the program
i = Year of the program, counting from 2004 to 2034

The inputs for annual nationwide emission reductions and costs used to calculate the aggregate cost-effectiveness are given in Appendix VI-C. Aggregate cost-effectiveness is produced by dividing DNAC by DNAE. The results are given in Section VI.E below.

E. Results

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The results of our cost-effectiveness analysis are given in Tables VI-8 (per-vehicle) and VI-9 (30 year aggregate). We calculated the per-vehicle cost-effectiveness of our standards for Tier 2 exhaust, Tier 2 evaporative, and gasoline sulfur as the total per-vehicle, discounted lifetime costs divided by the total per-vehicle, discounted lifetime tons reduced. Costs are given in Table VI-2. The tons reduced are calculated from the values in Table VI-7 as the difference between our NLEV baseline at our baseline sulfur level of 285 ppm, and our Tier 2 standards at our sulfur standard of 30 ppm. The aggregate values were calculated as described in Section D above.

Table VI-8. Per-vehicle cost-effectiveness of the Tier 2/gasoline sulfur standards

	<i>Credited costs (\$)</i>	<i>Uncredited costs (\$)</i>	<i>Tons NOx+NMHC</i>	<i>Credited \$/ton</i>	<i>Uncredited \$/ton</i>
Near term	188.63	242.96	0.10989	1717	2211
Long term	150.34	204.67	0.10989	1368	1863

Table VI-9. Aggregate cost-effectiveness of the standards

<i>Discounted aggregate vehicle & fuel costs</i>	<i>Discounted aggregate NMHC + NOx reduction (tons)</i>	<i>Discounted aggregate cost-effectiveness per ton</i>	<i>Discounted aggregate cost-effectiveness per ton with SO₂ and direct PM credit^a</i>
\$48.1 billion	23.5 million	\$2,047	\$1,311

^a \$13.8 billion credited to SO₂ (\$4800/ton), \$3.5 billion to direct PM (\$10,000/ton).

The values in Table VI-8 differ slightly from those in the NPRM for several reasons. First, the truck category has been expanded to include the larger trucks weighing greater than 8500 lb GVWR (the medium-duty passenger vehicles), causing a small increase in both the emission reductions and vehicle costs associated with our Tier 2 standards. Second, the baseline sulfur level changed from 305 ppm in the NPRM to 285 ppm in this final rule as described in Section VI.A.2. The reduction in baseline sulfur means that emissions from baseline vehicles were slightly lower than presented in the NPRM, and thus the emissions benefit of reducing sulfur to 30 ppm is also slightly lower. Third, there was a change in our approach to irreversibility, in that we revised our estimate of the irreversibility effect to encompass the range

of 20 to 65 percent, as described in Appendix B. Using the midpoint of 42.5 percent resulted in a small decrease in overall emission reductions resulting from Tier 2 vehicles operating on 30 ppm fuel. Finally, the costs associated with both fuel desulfurization and vehicle aftertreatment changed, as described in Sections V.A and V.B.

Because the primary purpose of cost-effectiveness is to compare our program to alternative programs, we made a comparison between the values in Tables VI-8 and VI-9 and the cost-effectiveness of other programs. Table VI-10 summarizes the cost effectiveness of several recent EPA actions for controlled emissions from mobile sources.

Table VI-10. Cost-effectiveness of Previously Implemented Mobile Source Programs (Costs Adjusted to 1997 Dollars)

<i>Program</i>	<i>\$/ton NO_x+NMHC</i>
2004 Highway HD Diesel stds	300
Non-road Diesel engine stds	410-650
Tier 1 vehicle controls	1,980-2,690 ²
NLEV	1,859
Marine SI engines	1,128-1,778
On-board diagnostics	2,228

By comparing the values from Table VI-8 and VI-9 to those in Table VI-10, we can see that the cost effectiveness of the Tier 2/gasoline sulfur standards falls within the range of these other programs. Engine-based standards (the 2004 highway heavy-duty diesel standards, the non-road diesel engine standards and the marine spark-ignited engine standards) have generally been less costly than our Tier 2/gasoline sulfur standards. Vehicle standards, most similar to today's proposal, have comparable or higher values than our Tier 2/gasoline sulfur program.

The primary advantage of making comparisons to previously implemented programs is that their cost-effectiveness values were based on a rigorous analysis and are generally accepted as representative of the efficiency with which those programs reduce emissions. Unfortunately, previously implemented programs can be poor comparisons because they may not be representative of the cost-effectiveness of potential future programs. For instance, the values in

² Cost-effectiveness of Tier 1 standards was originally calculated separately for NO_x and NMHC. A combined cost-effectiveness was recalculated for our proposal. See internal memorandum from David Korotney to Docket A-97-10, "Calculation of Tier 1 vehicle cost-effectiveness in terms of \$/ton NO_x+NMHC," document number II-B-03.

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Table VI-10 might imply that further reductions in NO_x and VOC from heavy-duty engines could be more cost-effective than the reductions that will be produced from our Tier 2/gasoline sulfur program. However, we do not believe that to be the case. While we are indeed developing a proposal for further control from heavy-duty engines, we expect that substantial further emission reductions will require advanced after-treatment devices. These devices will be more costly than methods use to meet our past standards, and will have difficulty functioning properly without changes to diesel fuel. We therefore expect that the cost effectiveness of future heavy-duty standards is not likely to be significantly less than the cost effectiveness of today's rule.

On the vehicle side, the last two sets of standards were Tier 1 and NLEV, which had cost effectiveness comparable to or higher than our Tier 2/gasoline sulfur standards. Compared to engines, these levels reflect the advanced (and more expensive) state of vehicle control technology, where standards have been in effect for a much longer period than for engines. Based on these results, Tier 2/gasoline sulfur appears to be a logical and consistent next step in vehicle control.

The most complete source of information on the cost-effectiveness of potential future programs is the rulemaking which revised the PM and ozone National Ambient Air Quality Standards (NAAQS)³. The Regulatory Impact Analysis (RIA) associated with that rulemaking contained a listing of potential future emission control programs and their cost-effectiveness.⁸ The listing categorizes control programs by mobile, point, and area source strategies for a total of 236 potential future programs. Although the majority of the programs in this list would most likely be implemented on a local or regional basis, they still provide the most complete information available on alternative programs and their associated cost-effectiveness.

Of the 236 potential future programs in the NAAQS RIA, 112 produced NO_x reductions with an average cost-effectiveness of \$13,000/ton, while 55 programs produced NMHC reductions with an average cost-effectiveness of \$5,000/ton. These values confirm that future controls will be more expensive than past controls.

We recognize that the cost effectiveness calculated for our program is not strictly comparable to the \$10,000/ton limit established in the NAAQS analyses since the technologies identified there can be targeted at the specific nonattainment areas of concern, while the Tier 2/gasoline sulfur program would apply nationwide. However, in dealing with the question of comparing local and national programs, it is also relevant to point out that, because of air transport, the need for NO_x control is a broad regional issue not confined to non-attainment areas only. To reach attainment, future controls will need to be applied over widespread areas of the

³ This rulemaking was remanded by the D.C. Circuit Court on May 14, 1999. However, the analyses completed in support of that rulemaking are still relevant, since they were designed to investigate the cost-effectiveness of a wide variety of potential future emission control strategies.

country. In the analyses supporting the recent NO_x standards for highway diesel engines,⁴ we looked at this question in some detail and concluded that the regions expected to impact ozone levels in ozone nonattainment areas accounted for over 85% of total NO_x emissions from a national heavy-duty engine control program. Similarly, NO_x emissions in attainment areas also contribute to particulate matter nonattainment problems in downwind areas. Thus, the distinction between local and national control programs for NO_x is less important than it might appear.

In summary, given the array of controls that will have to be implemented to make progress toward attaining and maintaining the NAAQS, we believe that the weight of the evidence from alternative means of providing substantial NO_x + NMHC emission reductions indicates that our Tier 2/gasoline sulfur proposal is cost-effective. This is true from the perspective of other mobile source control programs or from the perspective of other stationary source technologies that might be considered.

⁴ Final Regulatory Impact Analysis: Control of Emissions of Air Pollution from Highway Heavy-Duty Engines, September 16, 1997

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APPENDIX VI-A : Discounted Lifetime Tonnage Values for Exhaust Emissions

Stdnd	Veh clas	IM case	Sulfur	Fuel	NOx tons	NMHC tons
NLEV	LDT1	IM	30	Conventional	0.04614	0.01839
NLEV	LDT1	IM	30	RFG	0.04494	0.01565
NLEV	LDT1	No IM	30	Conventional	0.06646	0.03540
NLEV	LDT1	No IM	30	RFG	0.06478	0.03000
NLEV	LDT2	IM	30	Conventional	0.07705	0.02205
NLEV	LDT2	IM	30	RFG	0.07503	0.01878
NLEV	LDT2	No IM	30	Conventional	0.09894	0.03943
NLEV	LDT2	No IM	30	RFG	0.09642	0.03344
NLEV	LDT3	IM	30	Conventional	0.15696	0.05429
NLEV	LDT3	IM	30	RFG	0.15282	0.04632
NLEV	LDT3	No IM	30	Conventional	0.18307	0.07525
NLEV	LDT3	No IM	30	RFG	0.17836	0.06396
NLEV	LDT4	IM	30	Conventional	0.23321	0.06443
NLEV	LDT4	IM	30	RFG	0.22703	0.05498
NLEV	LDT4	No IM	30	Conventional	0.26188	0.08646
NLEV	LDT4	No IM	30	RFG	0.25512	0.07351
NLEV	LDV	IM	30	Conventional	0.03043	0.01124
NLEV	LDV	IM	30	RFG	0.02963	0.00957
NLEV	LDV	No IM	30	Conventional	0.03939	0.01892
NLEV	LDV	No IM	30	RFG	0.03839	0.01605
Tier 2	LDT1	IM	30	Conventional	0.02183	0.01839
Tier 2	LDT1	IM	30	RFG	0.02128	0.01565
Tier 2	LDT1	No IM	30	Conventional	0.04163	0.03540
Tier 2	LDT1	No IM	30	RFG	0.04060	0.03000
Tier 2	LDT2	IM	30	Conventional	0.02033	0.01832
Tier 2	LDT2	IM	30	RFG	0.01982	0.01559
Tier 2	LDT2	No IM	30	Conventional	0.04101	0.03535
Tier 2	LDT2	No IM	30	RFG	0.04000	0.02996
Tier 2	LDT3	IM	30	Conventional	0.02730	0.02130
Tier 2	LDT3	IM	30	RFG	0.02661	0.01813
Tier 2	LDT3	No IM	30	Conventional	0.05087	0.04114
Tier 2	LDT3	No IM	30	RFG	0.04961	0.03486
Tier 2	LDT4	IM	30	Conventional	0.02970	0.02152
Tier 2	LDT4	IM	30	RFG	0.02894	0.01831
Tier 2	LDT4	No IM	30	Conventional	0.05402	0.04138
Tier 2	LDT4	No IM	30	RFG	0.05268	0.03506
Tier 2	LDV	IM	30	Conventional	0.01364	0.01124
Tier 2	LDV	IM	30	RFG	0.01328	0.00957
Tier 2	LDV	No IM	30	Conventional	0.02237	0.01892
Tier 2	LDV	No IM	30	RFG	0.02181	0.01605
NLEV	LDT1	IM	80	Conventional	0.06296	0.01989
NLEV	LDT1	IM	80	RFG	0.06132	0.01694

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NLEV	LDT1	No IM	80	Conventional	0.08716	0.03669
NLEV	LDT1	No IM	80	RFG	0.08495	0.03110
NLEV	LDT2	IM	80	Conventional	0.08783	0.02329
NLEV	LDT2	IM	80	RFG	0.08552	0.01984
NLEV	LDT2	No IM	80	Conventional	0.11092	0.04051
NLEV	LDT2	No IM	80	RFG	0.10809	0.03436
NLEV	LDT3	IM	80	Conventional	0.15929	0.05585
NLEV	LDT3	IM	80	RFG	0.15508	0.04765
NLEV	LDT3	No IM	80	Conventional	0.18545	0.07659
NLEV	LDT3	No IM	80	RFG	0.18068	0.06510
NLEV	LDT4	IM	80	Conventional	0.23669	0.06632
NLEV	LDT4	IM	80	RFG	0.23042	0.05659
NLEV	LDT4	No IM	80	Conventional	0.26534	0.08807
NLEV	LDT4	No IM	80	RFG	0.25849	0.07489
NLEV	LDV	IM	80	Conventional	0.04183	0.01224
NLEV	LDV	IM	80	RFG	0.04073	0.01043
NLEV	LDV	No IM	80	Conventional	0.05250	0.01983
NLEV	LDV	No IM	80	RFG	0.05116	0.01683
Tier 2	LDT1	IM	80	Conventional	0.02903	0.01989
Tier 2	LDT1	IM	80	RFG	0.02828	0.01694
Tier 2	LDT1	No IM	80	Conventional	0.05338	0.03669
Tier 2	LDT1	No IM	80	RFG	0.05206	0.03110
Tier 2	LDT2	IM	80	Conventional	0.02685	0.01982
Tier 2	LDT2	IM	80	RFG	0.02617	0.01687
Tier 2	LDT2	No IM	80	Conventional	0.05236	0.03663
Tier 2	LDT2	No IM	80	RFG	0.05106	0.03105
Tier 2	LDT3	IM	80	Conventional	0.03626	0.02302
Tier 2	LDT3	IM	80	RFG	0.03533	0.01960
Tier 2	LDT3	No IM	80	Conventional	0.06519	0.04260
Tier 2	LDT3	No IM	80	RFG	0.06358	0.03611
Tier 2	LDT4	IM	80	Conventional	0.03954	0.02326
Tier 2	LDT4	IM	80	RFG	0.03853	0.01981
Tier 2	LDT4	No IM	80	Conventional	0.06935	0.04286
Tier 2	LDT4	No IM	80	RFG	0.06763	0.03633
Tier 2	LDV	IM	80	Conventional	0.01831	0.01224
Tier 2	LDV	IM	80	RFG	0.01783	0.01043
Tier 2	LDV	No IM	80	Conventional	0.02905	0.01983
Tier 2	LDV	No IM	80	RFG	0.02832	0.01683
NLEV	LDT1	IM	150	RFG	0.07523	0.01787
NLEV	LDT1	No IM	150	RFG	0.10209	0.03192
NLEV	LDT2	IM	150	RFG	0.09307	0.02059
NLEV	LDT2	No IM	150	RFG	0.11650	0.03502
NLEV	LDT3	IM	150	RFG	0.15830	0.04960
NLEV	LDT3	No IM	150	RFG	0.18399	0.06677
NLEV	LDT4	IM	150	RFG	0.29048	0.06432
NLEV	LDT4	No IM	150	RFG	0.32511	0.08390
NLEV	LDV	IM	150	RFG	0.05016	0.01106
NLEV	LDV	No IM	150	RFG	0.06201	0.01740
Tier 2	LDT1	IM	150	RFG	0.03424	0.01787

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Tier 2	LDT1	No IM	150	RFG	0.06180	0.03192
Tier 2	LDT2	IM	150	RFG	0.03157	0.01780
Tier 2	LDT2	No IM	150	RFG	0.06047	0.03187
Tier 2	LDT3	IM	150	RFG	0.04274	0.02066
Tier 2	LDT3	No IM	150	RFG	0.07544	0.03703
Tier 2	LDT4	IM	150	RFG	0.04667	0.02089
Tier 2	LDT4	No IM	150	RFG	0.08032	0.03728
Tier 2	LDV	IM	150	RFG	0.02170	0.01106
Tier 2	LDV	No IM	150	RFG	0.03386	0.01740
NLEV	LDT1	IM	300	RFG	0.09463	0.01901
NLEV	LDT1	No IM	300	RFG	0.12597	0.03297
NLEV	LDT2	IM	300	RFG	0.10225	0.02147
NLEV	LDT2	No IM	300	RFG	0.12671	0.03586
NLEV	LDT3	IM	300	RFG	0.16546	0.05410
NLEV	LDT3	No IM	300	RFG	0.19134	0.07062
NLEV	LDT4	IM	300	RFG	0.30482	0.06969
NLEV	LDT4	No IM	300	RFG	0.33951	0.08822
NLEV	LDV	IM	300	RFG	0.06330	0.01182
NLEV	LDV	No IM	300	RFG	0.07713	0.01812
Tier 2	LDT1	IM	300	RFG	0.04253	0.01901
Tier 2	LDT1	No IM	300	RFG	0.07537	0.03297
Tier 2	LDT2	IM	300	RFG	0.03909	0.01893
Tier 2	LDT2	No IM	300	RFG	0.07357	0.03291
Tier 2	LDT3	IM	300	RFG	0.05307	0.02197
Tier 2	LDT3	No IM	300	RFG	0.09198	0.03822
Tier 2	LDT4	IM	300	RFG	0.05802	0.02221
Tier 2	LDT4	No IM	300	RFG	0.09802	0.03848
Tier 2	LDV	IM	300	RFG	0.02709	0.01182
Tier 2	LDV	No IM	300	RFG	0.04157	0.01812
NLEV	LDT1	IM	300	Conventional	0.09718	0.02232
NLEV	LDT1	No IM	300	Conventional	0.12925	0.03887
NLEV	LDT2	IM	300	Conventional	0.10502	0.02520
NLEV	LDT2	No IM	300	Conventional	0.13003	0.04227
NLEV	LDT3	IM	300	Conventional	0.16996	0.06339
NLEV	LDT3	No IM	300	Conventional	0.19639	0.08304
NLEV	LDT4	IM	300	Conventional	0.30513	0.07907
NLEV	LDT4	No IM	300	Conventional	0.33962	0.10044
NLEV	LDV	IM	300	Conventional	0.06501	0.01386
NLEV	LDV	No IM	300	Conventional	0.07916	0.02134
Tier 2	LDT1	IM	300	Conventional	0.04366	0.02232
Tier 2	LDT1	No IM	300	Conventional	0.07729	0.03887
Tier 2	LDT2	IM	300	Conventional	0.04012	0.02222
Tier 2	LDT2	No IM	300	Conventional	0.07544	0.03880
Tier 2	LDT3	IM	300	Conventional	0.05446	0.02579
Tier 2	LDT3	No IM	300	Conventional	0.09432	0.04507
Tier 2	LDT4	IM	300	Conventional	0.05956	0.02608
Tier 2	LDT4	No IM	300	Conventional	0.10052	0.04538
Tier 2	LDV	IM	300	Conventional	0.02781	0.01386
Tier 2	LDV	No IM	300	Conventional	0.04264	0.02134

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NLEV	LDT1	IM	800	Conventional	0.13343	0.02424
NLEV	LDT1	IM	800	RFG	0.12953	0.02061
NLEV	LDT1	No IM	800	Conventional	0.18824	0.04059
NLEV	LDT1	No IM	800	RFG	0.16619	0.03424
NLEV	LDT2	IM	800	Conventional	0.11983	0.02668
NLEV	LDT2	IM	800	RFG	0.11660	0.02271
NLEV	LDT2	No IM	800	Conventional	0.14896	0.04306
NLEV	LDT2	No IM	800	RFG	0.14218	0.03688
NLEV	LDT3	IM	800	Conventional	0.18512	0.07818
NLEV	LDT3	IM	800	RFG	0.17755	0.06646
NLEV	LDT3	No IM	800	Conventional	0.22195	0.09850
NLEV	LDT3	No IM	800	RFG	0.20478	0.08046
NLEV	LDT4	IM	800	Conventional	0.28329	0.09441
NLEV	LDT4	IM	800	RFG	0.27546	0.08026
NLEV	LDT4	No IM	800	Conventional	0.30934	0.11431
NLEV	LDT4	No IM	800	RFG	0.30272	0.09452
NLEV	LDV	IM	800	Conventional	0.08982	0.01517
NLEV	LDV	IM	800	RFG	0.08723	0.01291
NLEV	LDV	No IM	800	Conventional	0.11664	0.02264
NLEV	LDV	No IM	800	RFG	0.10329	0.01903
Tier 2	LDT1	IM	800	Conventional	0.05863	0.02470
Tier 2	LDT1	IM	800	RFG	0.05683	0.02055
Tier 2	LDT1	No IM	800	Conventional	0.11031	0.04041
Tier 2	LDT1	No IM	800	RFG	0.09735	0.03416
Tier 2	LDT2	IM	800	Conventional	0.05357	0.02459
Tier 2	LDT2	IM	800	RFG	0.05191	0.02045
Tier 2	LDT2	No IM	800	Conventional	0.10723	0.04033
Tier 2	LDT2	No IM	800	RFG	0.09464	0.03413
Tier 2	LDT3	IM	800	Conventional	0.07307	0.02848
Tier 2	LDT3	IM	800	RFG	0.07083	0.02369
Tier 2	LDT3	No IM	800	Conventional	0.13467	0.04681
Tier 2	LDT3	No IM	800	RFG	0.11874	0.03979
Tier 2	LDT4	IM	800	Conventional	0.08008	0.02883
Tier 2	LDT4	IM	800	RFG	0.07763	0.02398
Tier 2	LDT4	No IM	800	Conventional	0.14375	0.04714
Tier 2	LDT4	No IM	800	RFG	0.12673	0.04006
Tier 2	LDV	IM	800	Conventional	0.03766	0.01556
Tier 2	LDV	IM	800	RFG	0.03653	0.01293
Tier 2	LDV	No IM	800	Conventional	0.06155	0.02244
Tier 2	LDV	No IM	800	RFG	0.05435	0.01930

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APPENDIX VI-B : Discounted Lifetime Tonnage Values for Evaporative Emissions

Standard	Veh class	IM case	Fuel	NMHC tons
2.0 gpt enhanced	LDT1	IM	Conventional	0.02835
2.0 gpt enhanced	LDT1	IM	RFG	0.01793
2.0 gpt enhanced	LDT1	No IM	Conventional	0.06791
2.0 gpt enhanced	LDT1	No IM	RFG	0.03537
2.0 gpt enhanced	LDT2	IM	Conventional	0.02835
2.0 gpt enhanced	LDT2	IM	RFG	0.01793
2.0 gpt enhanced	LDT2	No IM	Conventional	0.06791
2.0 gpt enhanced	LDT2	No IM	RFG	0.03537
2.0 gpt enhanced	LDT3	IM	Conventional	0.03216
2.0 gpt enhanced	LDT3	IM	RFG	0.01972
2.0 gpt enhanced	LDT3	No IM	Conventional	0.08730
2.0 gpt enhanced	LDT3	No IM	RFG	0.04301
2.0 gpt enhanced	LDT4	IM	Conventional	0.03216
2.0 gpt enhanced	LDT4	IM	RFG	0.01972
2.0 gpt enhanced	LDT4	No IM	Conventional	0.08730
2.0 gpt enhanced	LDT4	No IM	RFG	0.04301
2.0 gpt enhanced	LDV	IM	Conventional	0.02184
2.0 gpt enhanced	LDV	IM	RFG	0.01208
2.0 gpt enhanced	LDV	No IM	Conventional	0.04722
2.0 gpt enhanced	LDV	No IM	RFG	0.02268
Tier 2	LDT1	IM	Conventional	0.02612
Tier 2	LDT1	IM	RFG	0.01622
Tier 2	LDT1	No IM	Conventional	0.06595
Tier 2	LDT1	No IM	RFG	0.03389
Tier 2	LDT2	IM	Conventional	0.02612
Tier 2	LDT2	IM	RFG	0.01622
Tier 2	LDT2	No IM	Conventional	0.06595
Tier 2	LDT2	No IM	RFG	0.03389
Tier 2	LDT3	IM	Conventional	0.02994
Tier 2	LDT3	IM	RFG	0.01797
Tier 2	LDT3	No IM	Conventional	0.08551
Tier 2	LDT3	No IM	RFG	0.04168
Tier 2	LDT4	IM	Conventional	0.02994
Tier 2	LDT4	IM	RFG	0.01797
Tier 2	LDT4	No IM	Conventional	0.08551
Tier 2	LDT4	No IM	RFG	0.04168
Tier 2	LDV	IM	Conventional	0.02028
Tier 2	LDV	IM	RFG	0.01101
Tier 2	LDV	No IM	Conventional	0.04567
Tier 2	LDV	No IM	RFG	0.02158

APPENDIX VI-C :Aggregate Annual Tons and Costs

	<i>NO_x</i> (tons)	<i>VOC</i> (tons)	<i>PM₁₀</i> (tons)	<i>SO_x</i> (tons)	<i>Fuel cost</i> (\$Million)	<i>Vehicle costs</i> (\$Million)
2004	338,231	85,688	14,127	123,849	1,618	269
2005	469,037	91,310	17,307	147,096	1,819	531
2006	748,269	136,232	22,865	189,462	2,268	834
2007	856,471	143,507	23,427	193,779	2,302	1,383
2008	977,740	153,281	24,049	198,127	2,526	1,556
2009	1,105,762	165,486	24,609	202,374	2,555	1,578
2010	1,235,882	178,886	25,131	206,480	2,553	1,500
2011	1,364,290	191,563	25,728	210,601	2,577	1,432
2012	1,488,166	204,728	26,275	214,688	2,600	1,362
2013	1,605,738	217,743	26,836	218,668	2,623	1,354
2014	1,715,040	230,828	27,404	222,591	2,645	1,351
2015	1,816,767	244,080	27,950	226,458	2,648	1,357
2016	1,911,270	256,575	28,504	230,288	2,670	1,364
2017	1,998,345	269,066	29,042	234,068	2,690	1,371
2018	2,078,026	281,325	29,607	237,813	2,710	1,378
2019	2,151,690	293,408	30,144	241,517	2,161	1,385
2020	2,220,210	305,470	30,685	245,179	2,153	1,392
2021	2,284,625	315,447	31,220	248,825	2,134	1,399
2022	2,345,739	325,009	31,762	252,461	2,166	1,406
2023	2,404,807	334,331	32,288	256,049	2,200	1,413
2024	2,461,670	343,560	32,813	259,638	2,233	1,420
2025	2,523,034	352,415	33,339	263,215	2,266	1,427
2026	2,573,768	361,364	33,864	266,785	2,299	1,434
2027	2,623,506	370,210	34,390	270,347	2,332	1,441
2028	2,693,468	384,152	34,944	273,906	2,365	1,448
2029	2,745,571	392,438	35,474	277,462	2,398	1,456
2030	2,795,551	400,968	36,004	281,016	2,431	1,463
2031	2,853,945	411,917	36,540	284,581	2,464	1,470
2032	2,911,214	422,174	37,078	288,138	2,497	1,478
2033	2,967,538	432,141	37,614	291,695	2,530	1,485
2034	3,020,448	441,308	38,146	295,253	2,563	1,492

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Chapter VI References

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